



## Study of Extreme Weather Events (hot & cold day or wave) over Bihar Region

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### Article History

Received on: 13-05-2015  
Accepted on: 26-05-2015  
Published on: 31-05-2015

### Keyword

Heat wave  
Cold wave  
Hot day  
Cold day  
decade

### ABSTRACT

In this paper an attempt has been made to study the heat wave /cold wave and hot /cold days for Bihar region during 46 years of data (1969-2014). The representative months have been taken from December to February and March to June for cold wave/ cold days and hot wave /hot days respectively. The results obtained from decade analysis shows that the frequency of the hot wave /hot days increased during the last decade (2005 to 2014) almost for all the stations of Bihar region. In the similar manner the frequency of the cold wave /cold days also increases during last two decades (1995 to 2004 and 2005 to 2014) over the region. The gaps in the data of part time observatories have not been taken into account in the final decision.

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## I. INTRODUCTION

Bihar state in the eastern part of India is a major agricultural hub from ancient time. The state weather or climate is greatly affected by the Himalayas and Ganga plateau. The rise in temperature starts from the months of March just after the winter season ends in February. The day to day weather data is received in synoptic hours from 4 departmental and 8 part time observatories. Care has been taken to maintain the accuracy and reliability of the data of the regular observatories. Part time an observatory data is taken every day by meteorological data trend personals but the accuracy /reliability of data is affected either in new replacement of the person or faulty instruments. The large data gaps in the data of the part time observatories are due to the above said reasons. Some of the observatories are defunct and discontinuity in the data series exists. The temperature extremes (hot /cold) affect the agriculture production and socio-economic growth of the country. The knowledge of the occurrences of extreme temperature events helps in improving the forecasting skill and accuracy of forecasting. This helps to understand better disaster management and weather calamities. Various authors (De et al, 2005, Pi et al, 2004 WMO, 2002, Kalsi and Pareek, 2001, De and Mukhopadhyay, 1998 and Raghavan, 1966) in the past studied the effect of heat wave /severe heat waves in different parts of India in general or in association with some weather events. In the recent past, the studies have been conducted by several meteorologists on extreme cold events (Das & Mamgain, 2011, Raghavan, 1967).

## II. DATA AND METHODOLOGY

The meteorological data used in the study is taken from National Data Centre (NDC) Pune and Meteorological Centre, Patna. The following criteria as per IMD guidelines for heat wave /hot days and cold wave /cold day have been used.

**Cold day:** When the maximum temperature is less than or equal to 16 Deg C in plains.

**Cold wave:** Wind chill factor is taken into account while deciding the cold wave situation. Departure of wind chill effective minimum temperature (WCTn) from normal  $-5^{\circ}\text{C}$  to  $-6^{\circ}\text{C}$  where normal minimum temperature  $\geq 10^{\circ}\text{C}$  or  $-4^{\circ}\text{C}$  to  $-5^{\circ}\text{C}$ , in case normal minimum temperature is  $\leq 10^{\circ}\text{C}$ . Also cold wave is declared when WCTn is  $\leq 0^{\circ}\text{C}$  irrespective of the minimum temperature of the stations. Severe cold wave conditions persists if the departure from normal is  $\geq -6^{\circ}\text{C}$  ( $T_{\min} \geq 10^{\circ}\text{C}$ ) or  $\geq -5^{\circ}\text{C}$ . ( $T_{\min} \leq 10^{\circ}\text{C}$ ).

**Hot day:** Whenever the maximum temperature remains  $40^{\circ}\text{C}$  or more and minimum remains  $5^{\circ}\text{C}$  or more above normal, provided it is not satisfying the heat wave criteria.

**Heat wave /severe heat wave:** Departure  $+4^{\circ}\text{C}$  to  $+5^{\circ}\text{C}$ , when normal maximum temperature of the station is  $\geq 40^{\circ}\text{C}$  and  $+5^{\circ}\text{C}$  to  $+6^{\circ}\text{C}$  in case of normal maximum temperature of the station is  $\leq 40^{\circ}\text{C}$ . and for severe heat wave one degree centigrade or more for above said criteria. If the actual maximum temperature ( $T_{\max}$ )  $\geq 45^{\circ}\text{C}$ , then heat wave is declared irrespective of normal  $T_{\max}$ .

## III. RESULTS AND DISCUSSION

Heat wave or cold wave conditions affect the lives of the people over the area. Extreme positive (negative) departure from normal temperature results heat wave (cold wave) during summer (winter) months of the year. The rising temperature over Bihar region starts during pre -monsoon season and often continues till June. Similarly, cold conditions starts affecting Bihar from December months and often continues till February. The observational data from eight places (Patna, Gaya, Bhagalpur, Purnea, Supaul, Chapra, Dehri and Muzaffarpur) have been utilized for the present work. The results obtained from the study are shown in figures 1 (a-h) & 2(a-h) for cold wave and heat wave respectively. It may be seen that the number of events both heat and cold wave are increasing in last two decades. The

frequencies of heat /cold days or waves are different in North (Purnea, Supaul, Muzaffarpur), South (Gaya, Patna, Dehri), East (Bhagalpur) and West Bihar (Muzaffarpur). The temperature during summer and winter is influenced by transient disturbances in mid -latitude westerlies called western disturbances along with regional changes. The details distribution of heat /cold days or wave brought out from the study have been given in Tables 1 (a,b), 2 (a -d). The frequencies of each year are different depending on the weather systems affected over the area and it was very difficult to decide the trend of events on yearly basis. So, decade analysis of eight places of Bihar is done and results have been given in Tables 3 (a-c) and figures 3 (a,b). It has been brought out from the analysis that the heat wave conditions that occurred on eight places over Bihar showing increasing trend in last decade (2005-2014). Similarly, cold wave conditions have also been increased during last two decades (1995-2004 & 2005-2014). Observational data analysis have shown that cold days for Patna and Gaya increasing trend, figs 1(a,b) in comparison to Bhagalpur, Supaul, Chapra and Purnea, districts. In some places the change is asymmetric rather than systematic increase or decrease, figs 1, 2 (a-h).

#### IV. CONCLUDING REMARKS

Extreme weather and its impact on socio-economic conditions are well known from ancient times. In recent decades the frequencies of heat/cold days or waves have changed and more vulnerable due to the rapid alteration of the natural resources and urbanization. The following points have been highlighted from the study:

1. Frequency of heat wave/days have shown increasing trend over Bihar region during last decade (2005-2014)
2. Frequency of cold wave /days have also shown increasing trend over Bihar region during last two decades (1995-2004 and 2005-2014).
3. The present study is helpful to understand better the occurrences of temperature extremes over the region.

#### V. ACKNOWLEDGEMENTS

The author is grateful to the Director General of IMD for providing the data of this study. The supporting help of MC -Patna staff in collecting the data is duly acknowledged.

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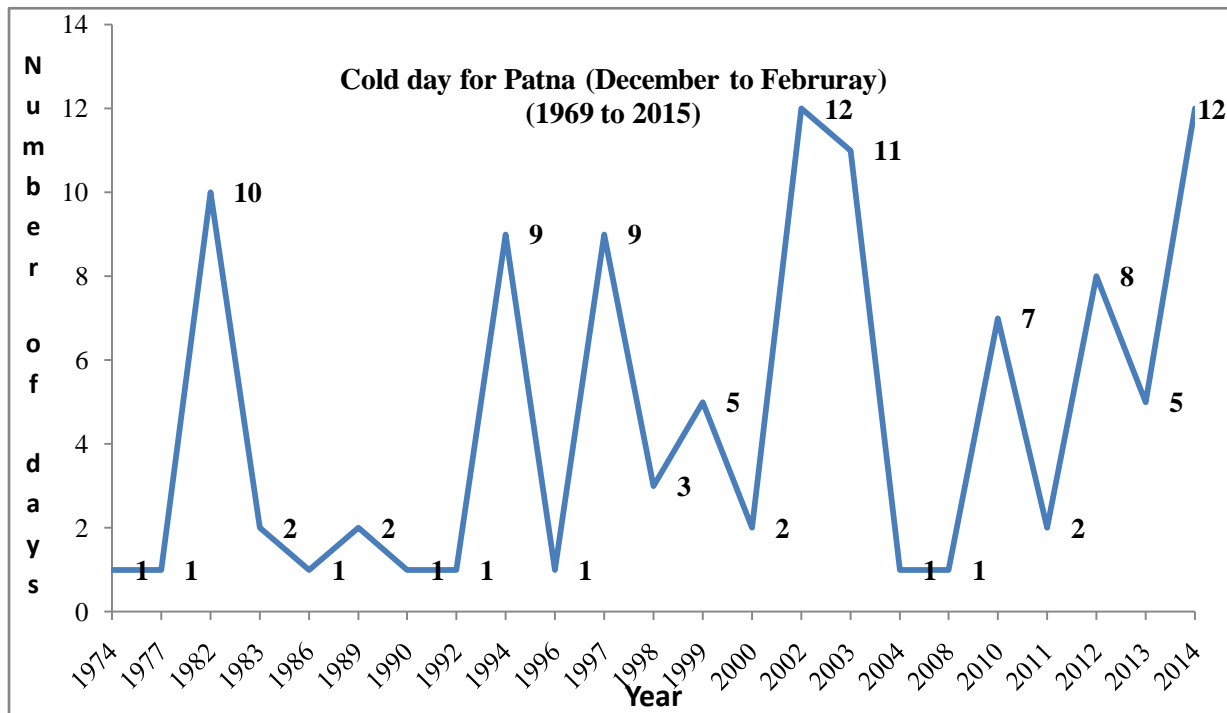


Figure 1 (a) : Cold day for Patna

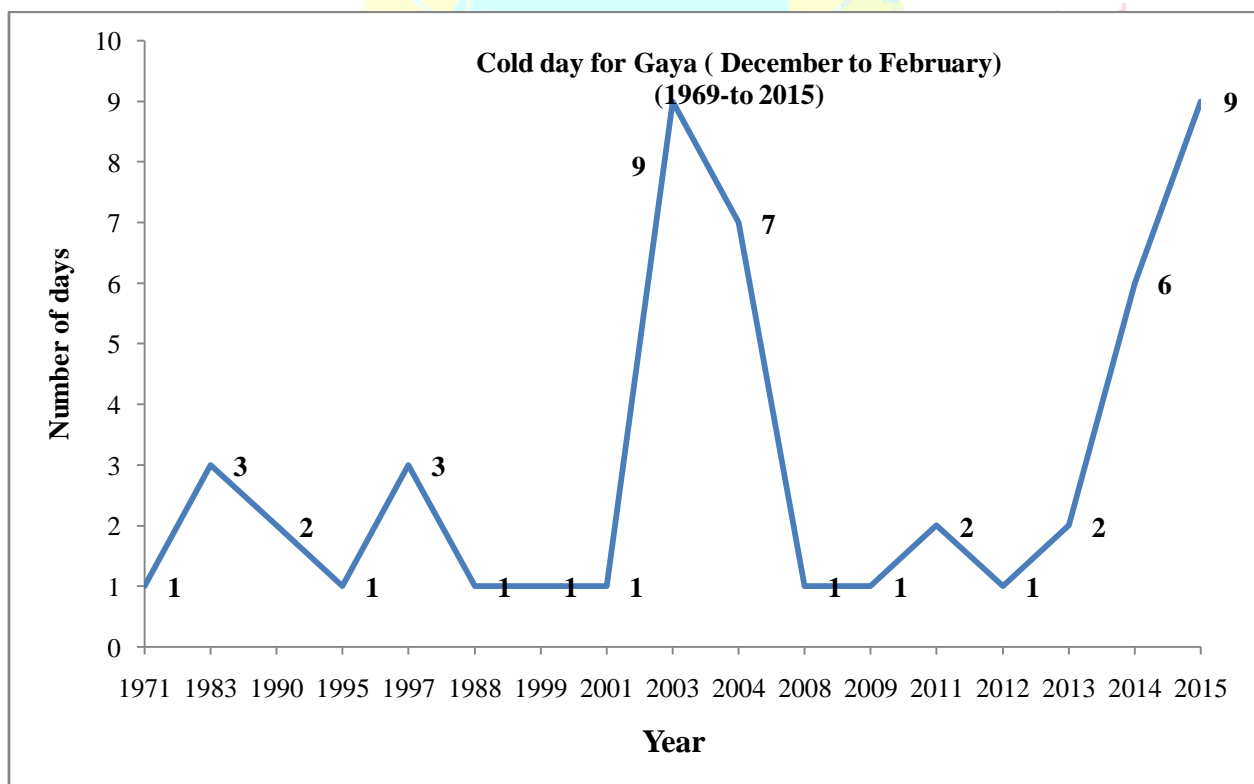


Figure 1 (b): Cold day for Gaya

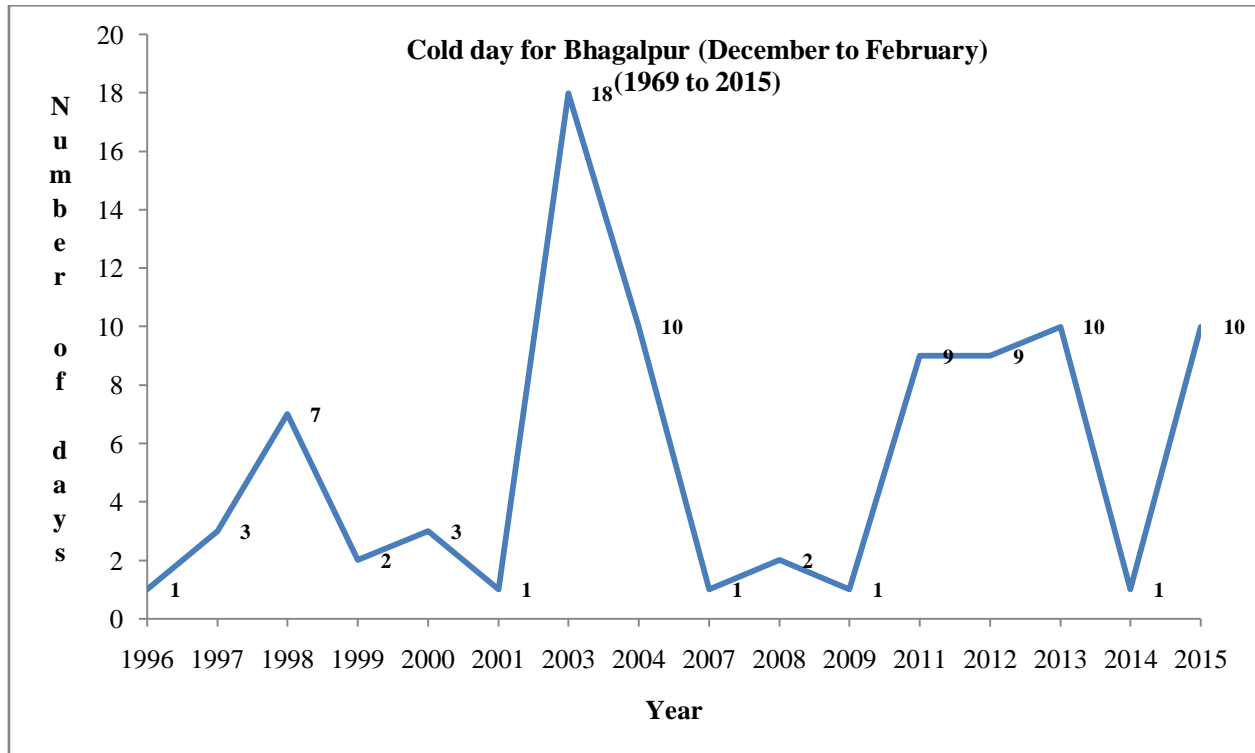


Figure 1 (c): Cold day for Bhagalpur

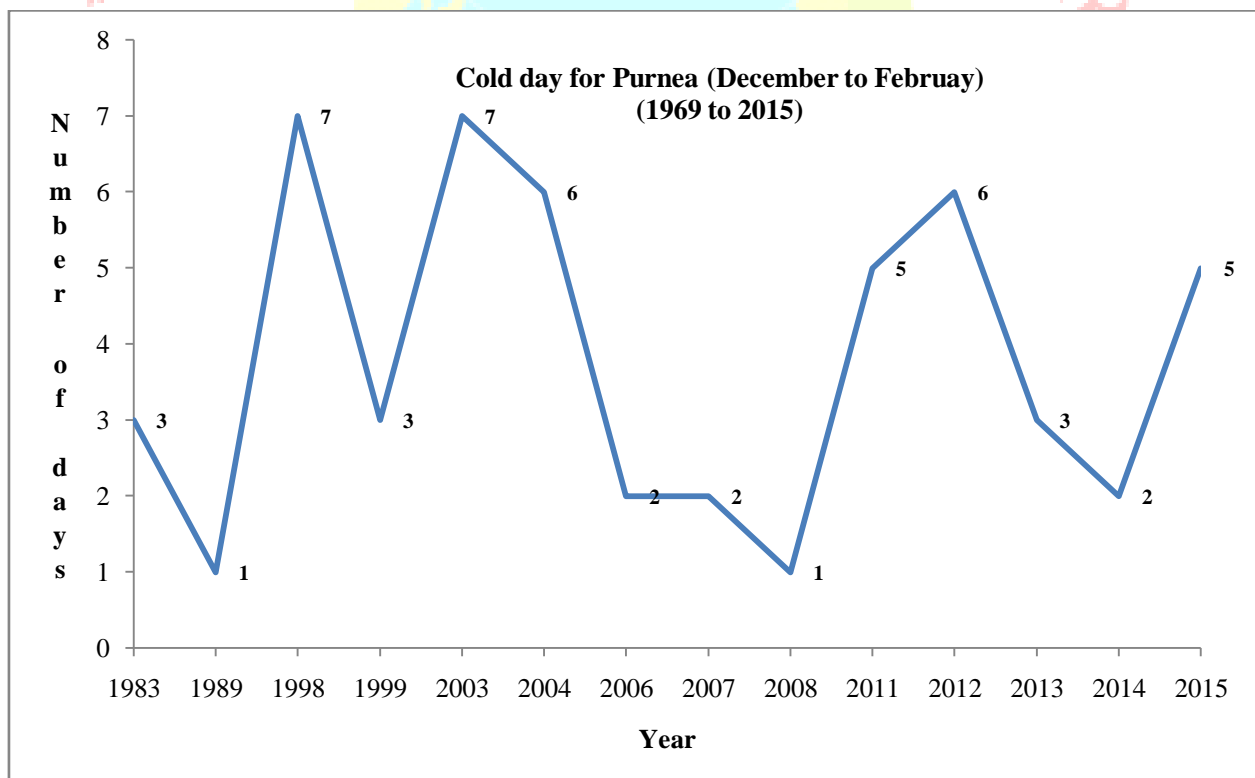


Figure 1 (d): Cold day for Purnea

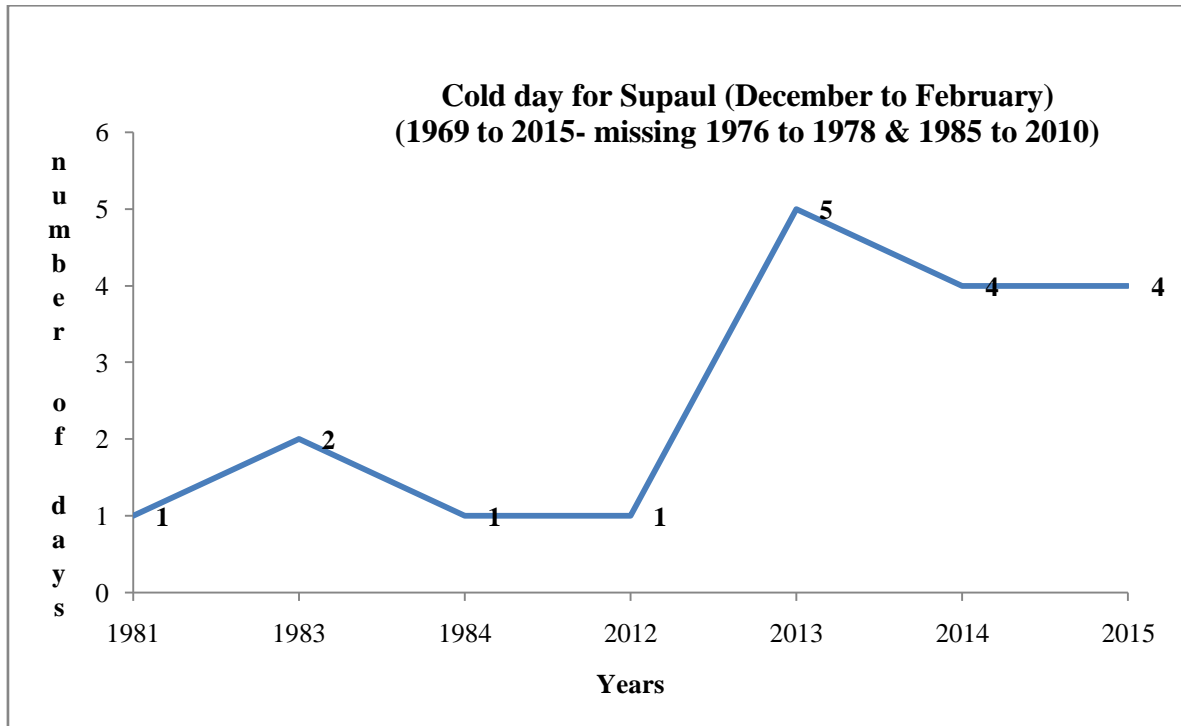


Figure 1 (e): Cold day for Supaul

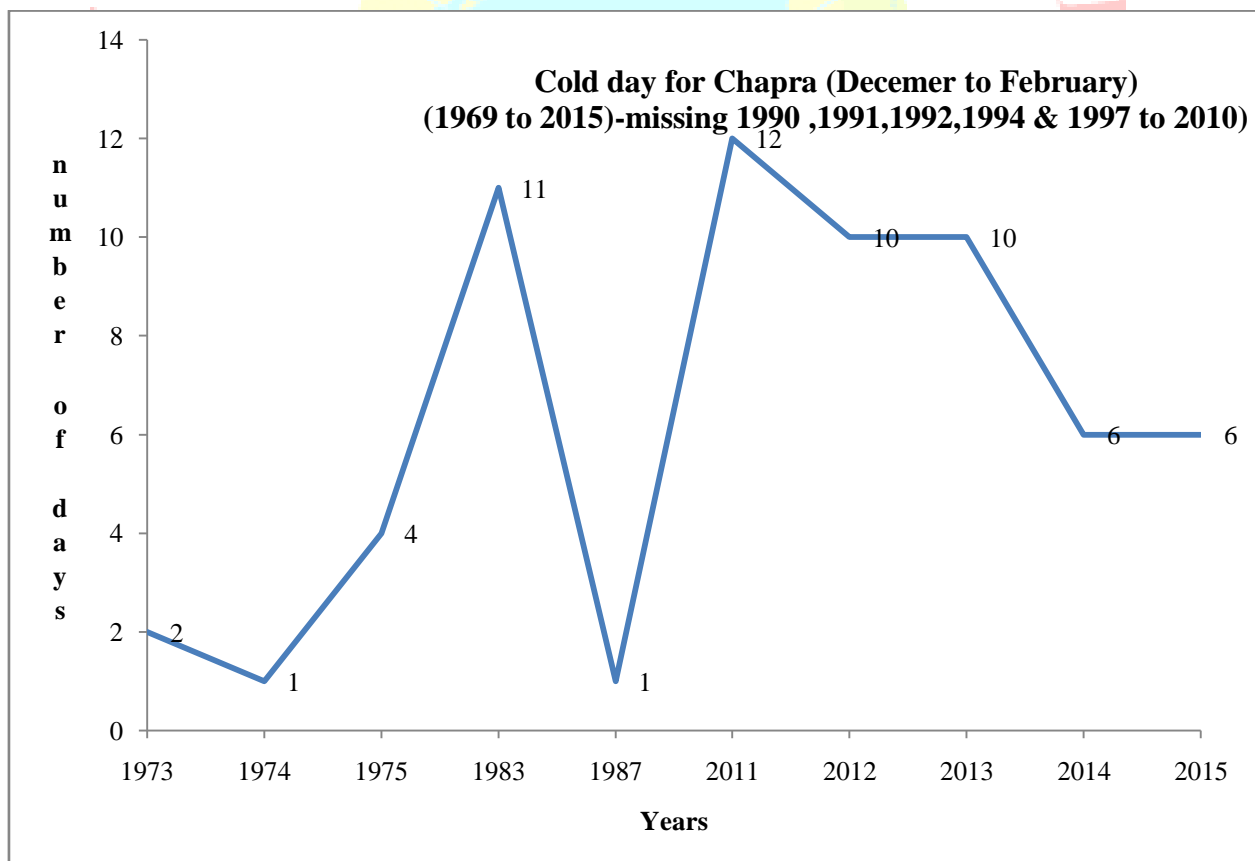


Figure 1 (f): Cold day for Chapra

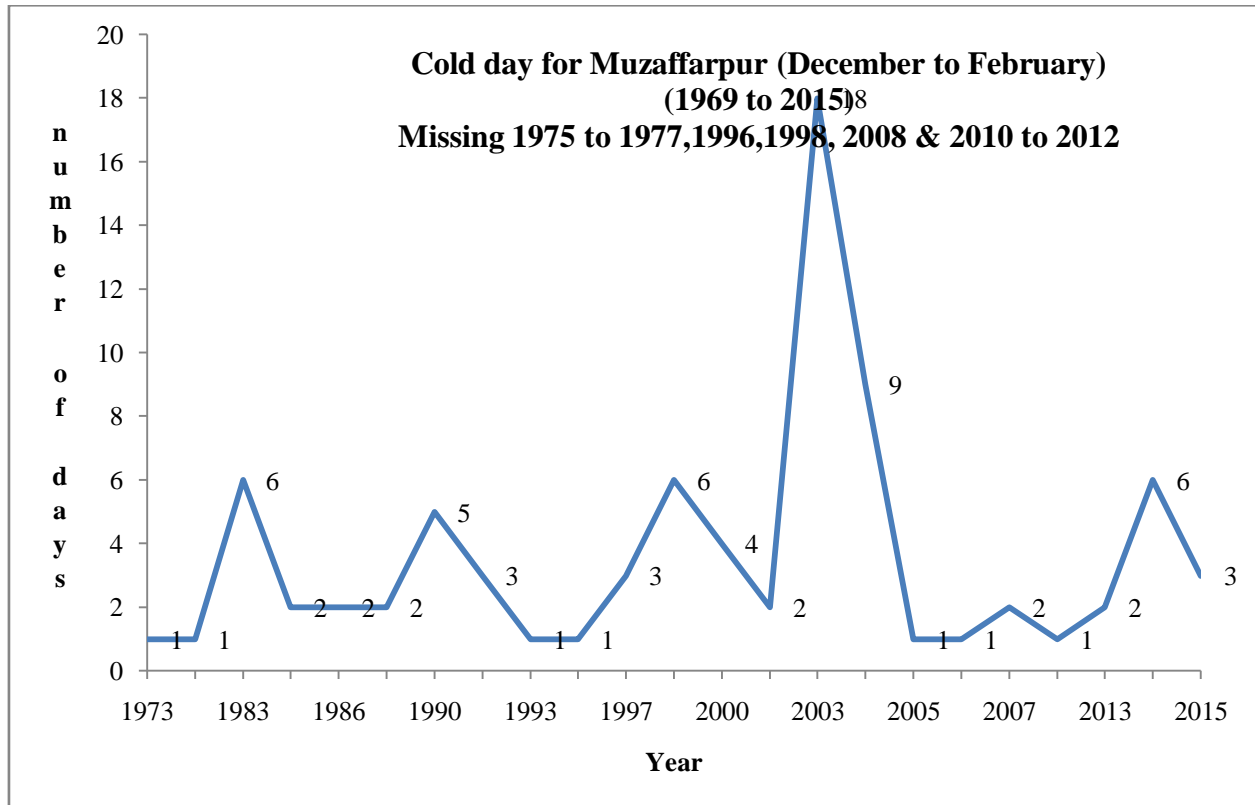


Figure 1 (g): Cold day for Muzaffarpur

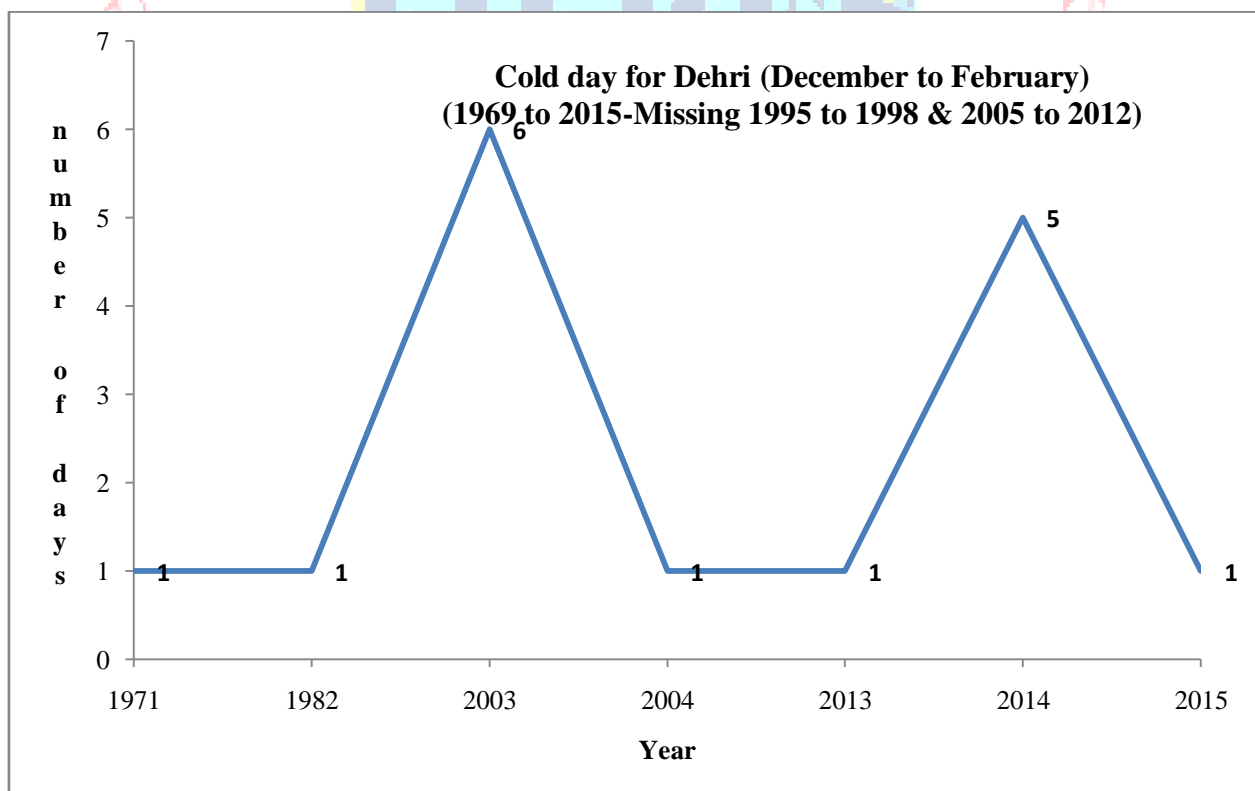


Figure 1 (h): Cold day for Dehri

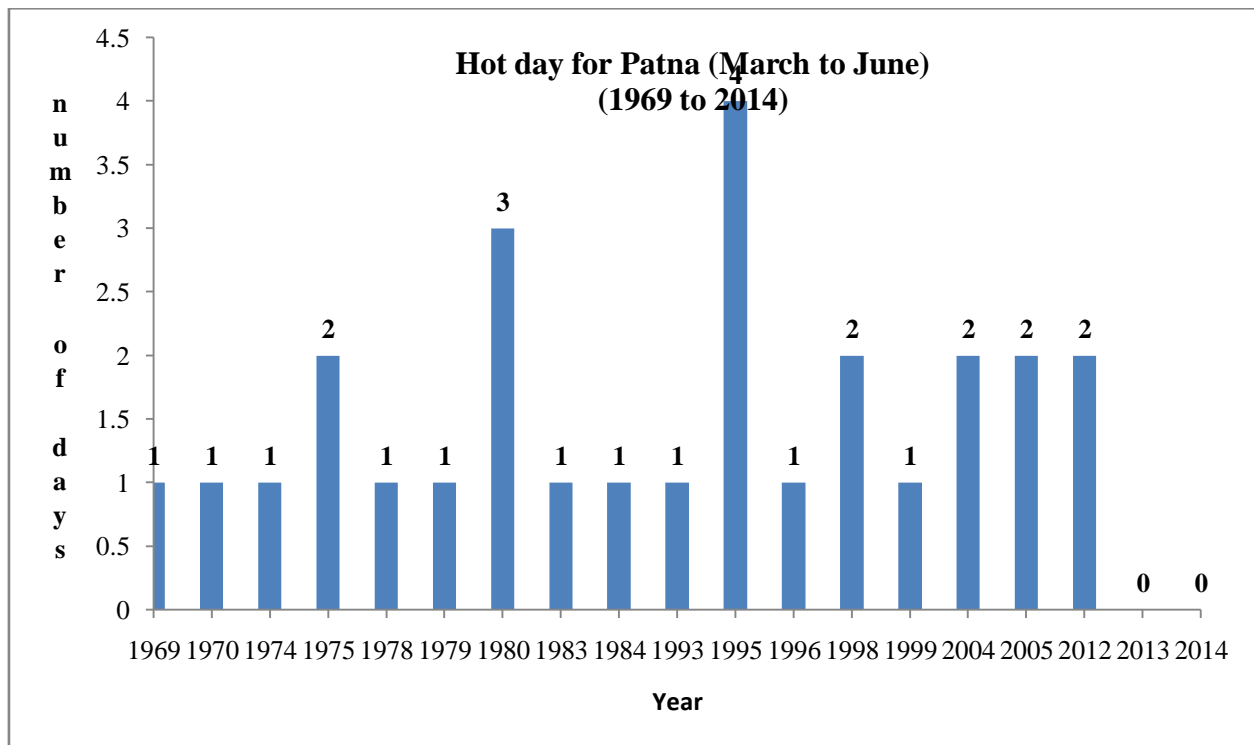


Figure 2 (a): Hot day for Patna

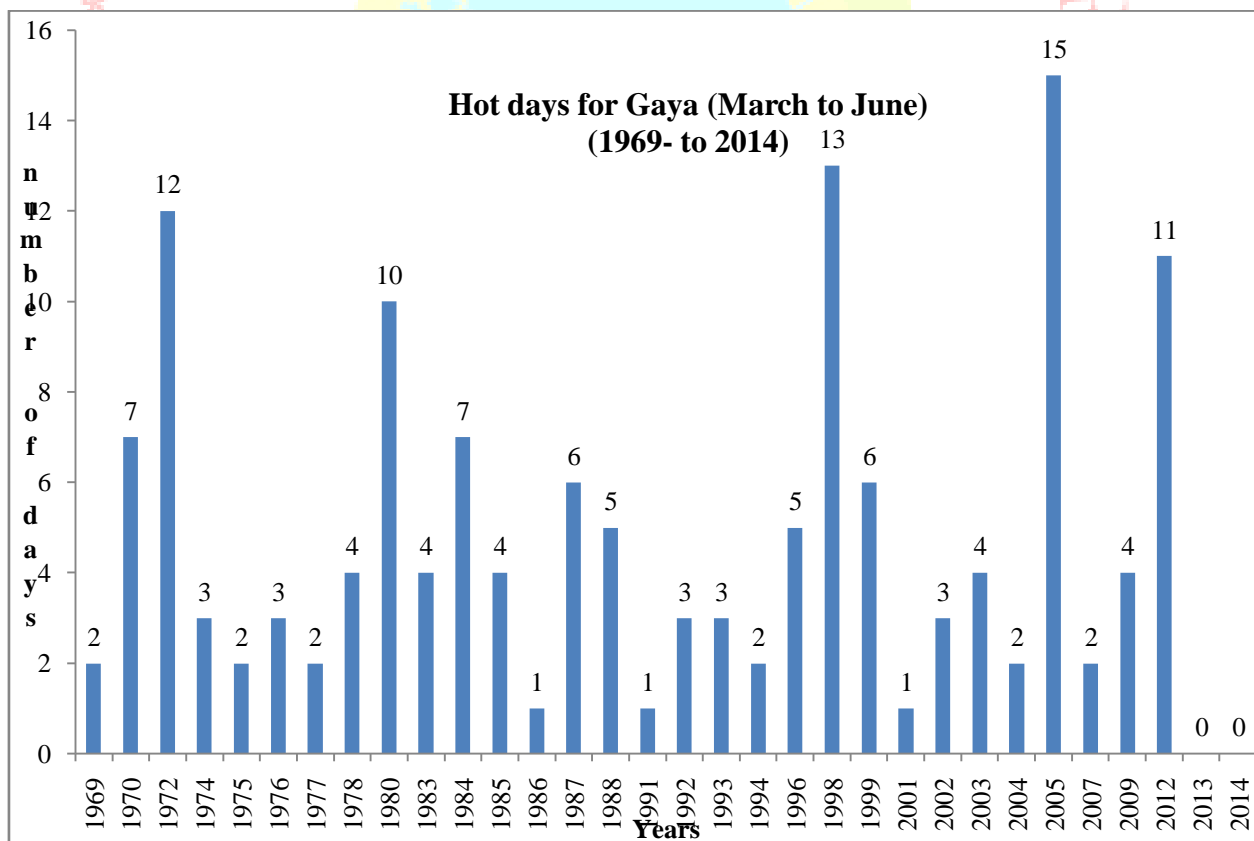


Figure 2 (b): Hot day for Gaya



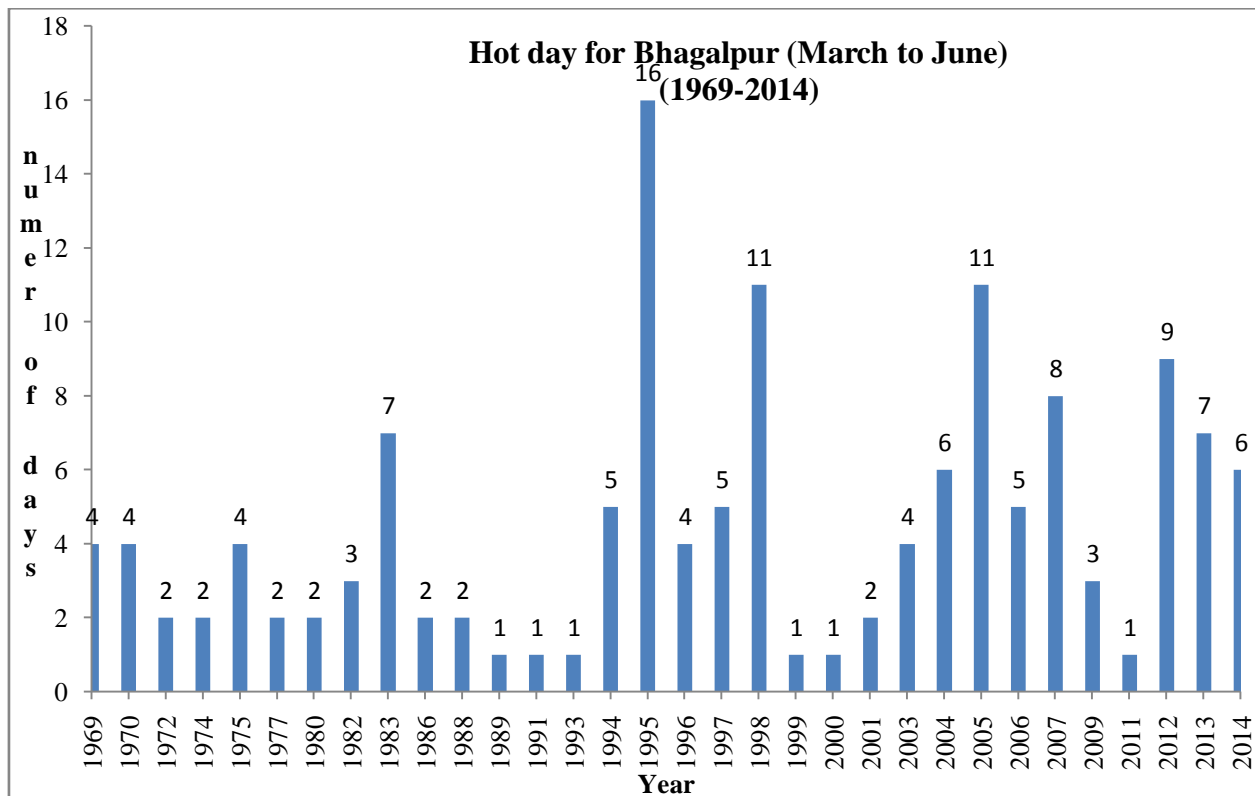


Figure 2 (c): Hot day for Bhagalpur

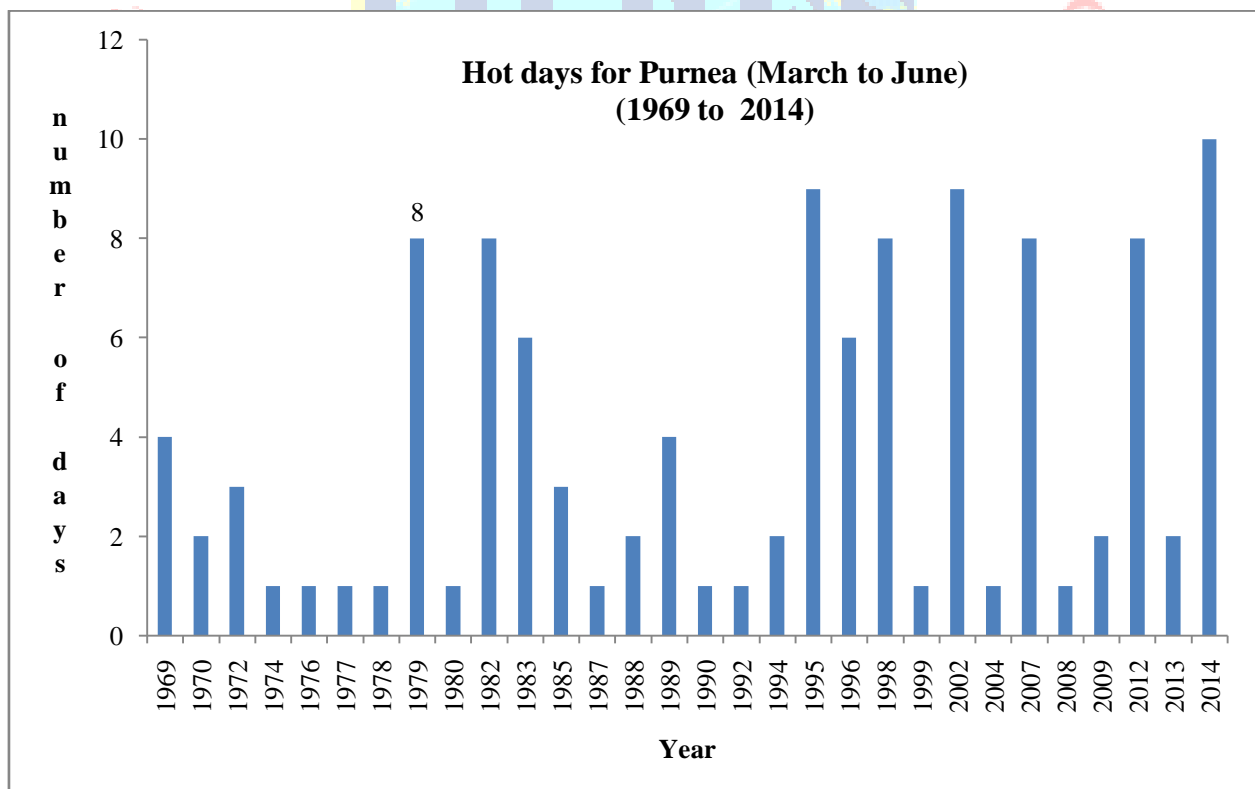


Figure 2 (d): Hot days for Purnea

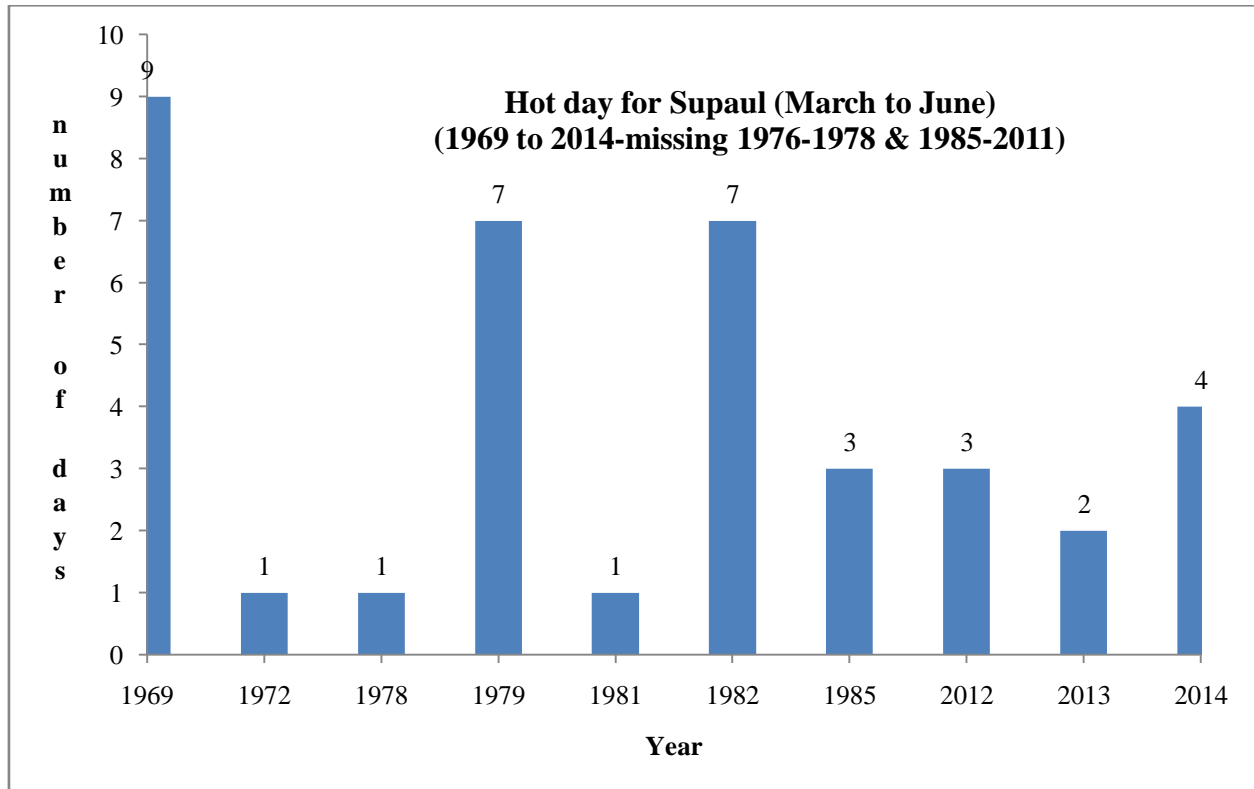


Figure 2 (e): Hot days for Supaul

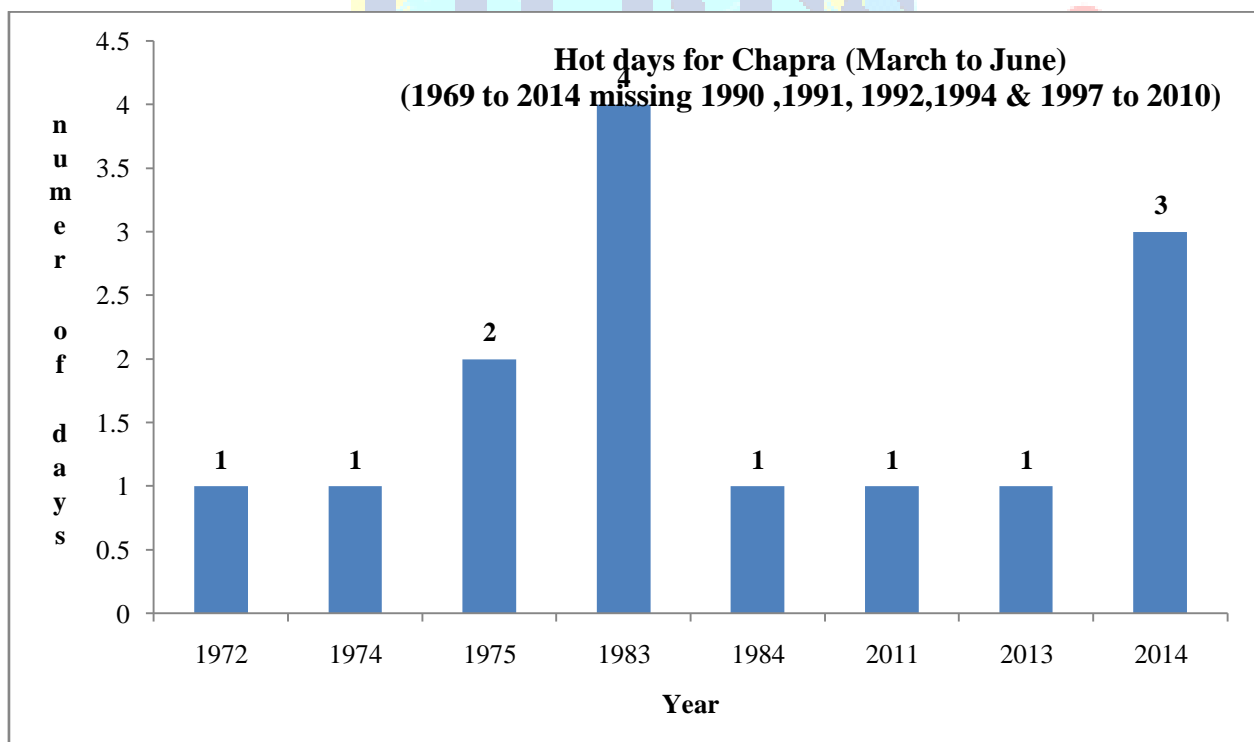


Figure 2 (f); Hot days for Chapra

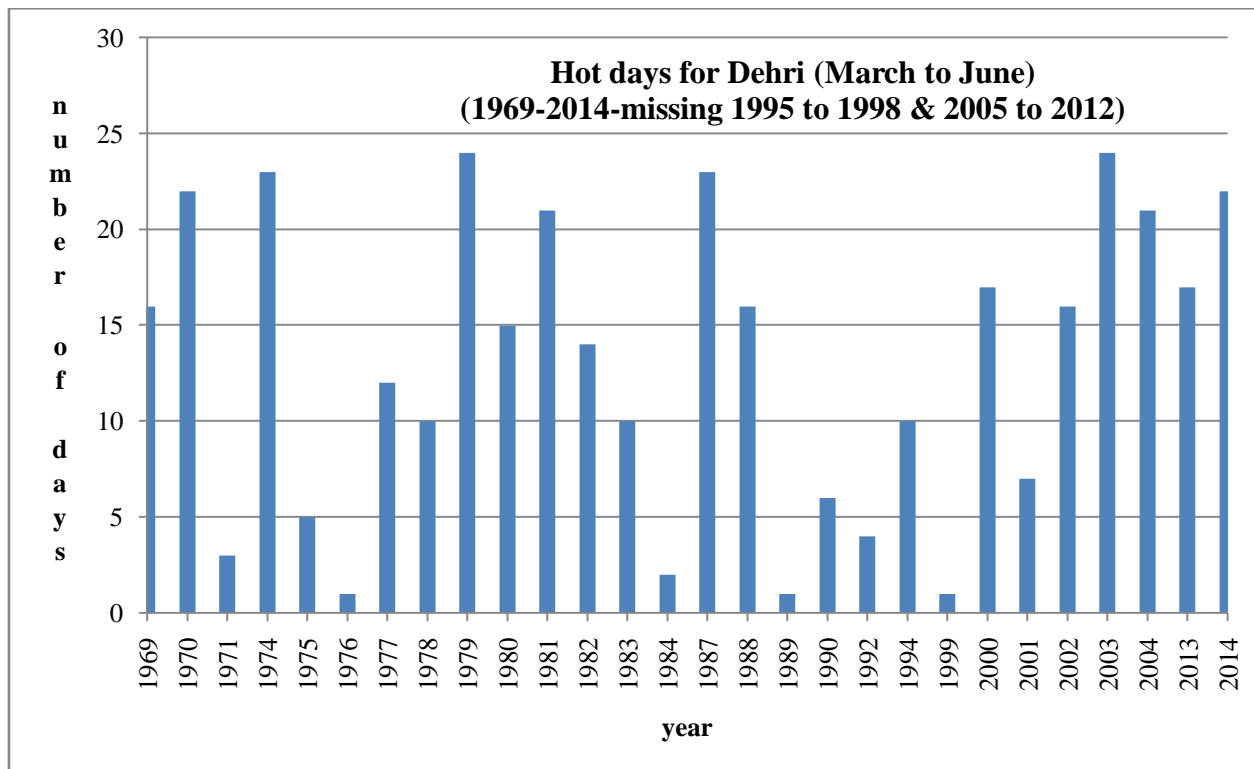


Figure 2 (g): Hot days for Dehri

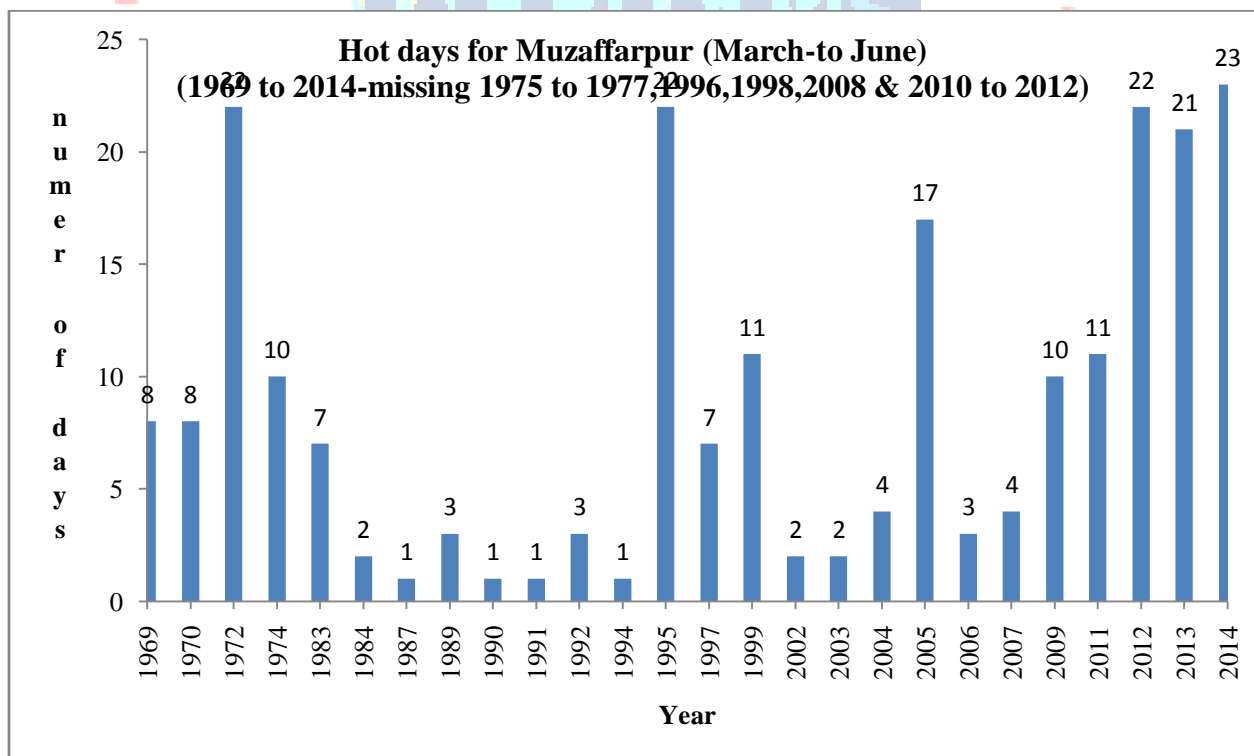


Figure 2 (h): Hot days for Muzaffarpur

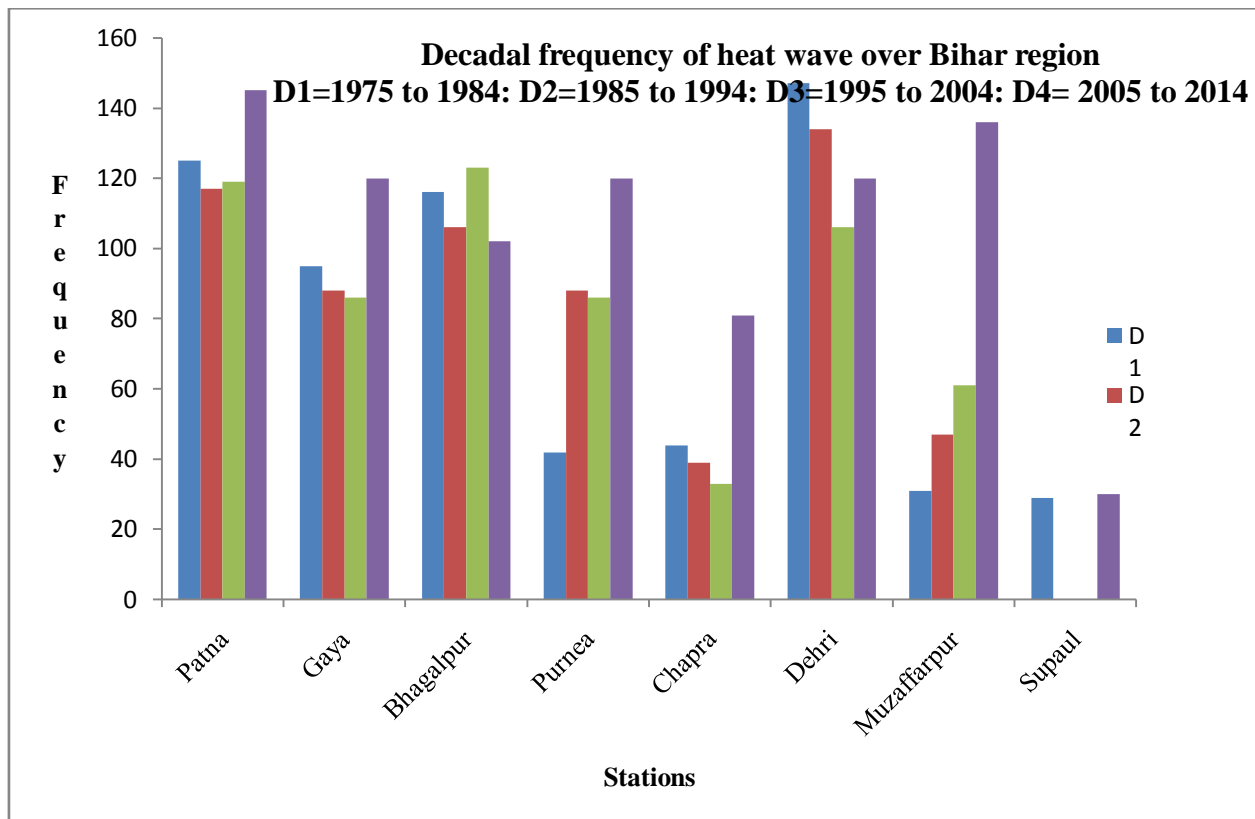


Figure 3 (a): Decadal frequency of heat wave over Bihar region

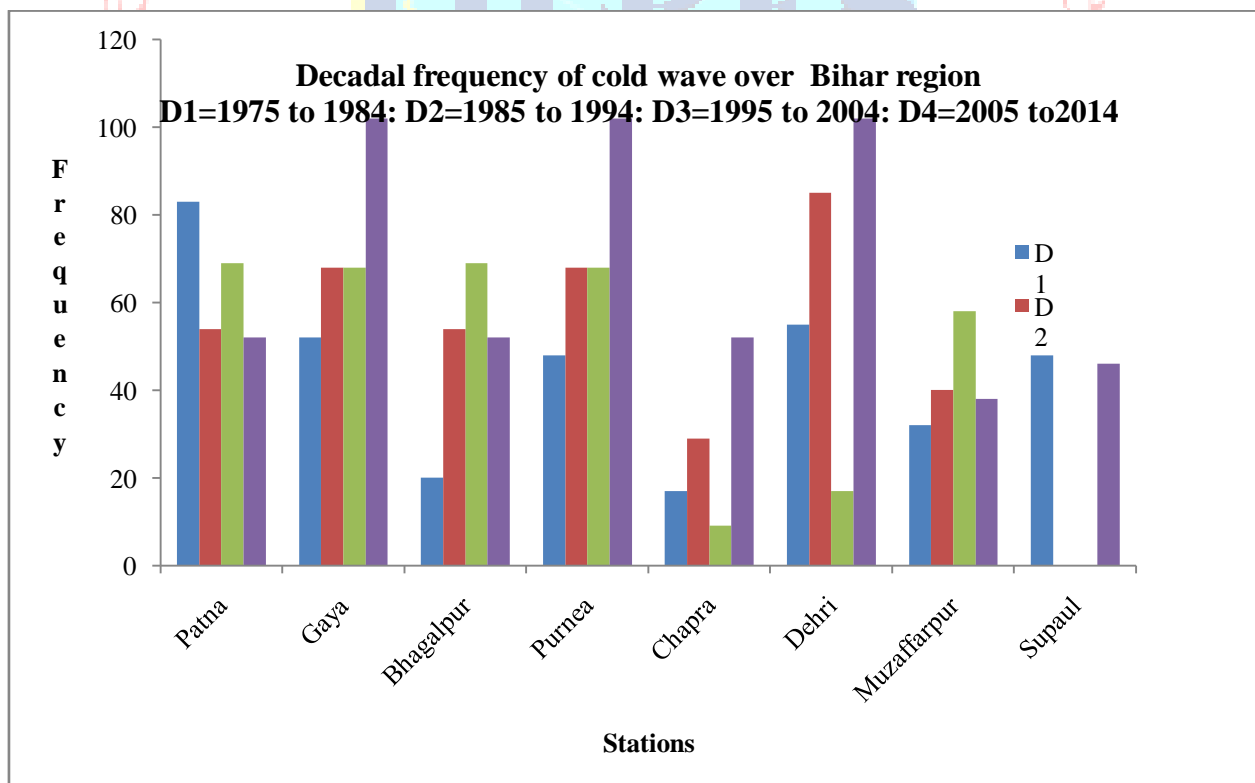


Figure 3 (b): Decadal frequency of cold wave over Bihar region

**Table 1 (a): Number of hot days (HD) and cold days (CD) over Bihar region**

Year	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	
	Patna		Gaya		Bhagalpur		Purnia		
1969	1	0	2	0	4	0	4	0	
1970	1	0	7	0	4	0	2	0	
1971	0	0	0	1	0	0	0	0	
1972	0	0	12	0	2	0	3	0	
1973	0	0	0	0	0	0	0	0	
1974	1	1	3	0	2	0	1	0	
1975	2	0	2	0	4	0	0	0	
1976	0	0	3	0	0	0	1	0	
1977	0	1	2	0	2	0	1	0	
1978	1	0	4	0	0	0	1	0	
1979	1	0	0	0	0	0	8	0	
1980	3	0	10	0	2	0	1	0	
1981	0	0	0	0	0	0	0	0	
1982	0	10	0	0	3	0	8	0	
1983	1	2	4	3	7	0	6	3	
1984	1	0	7	0	0	0	0	0	
1985	0	0	4	0	0	0	3	0	
1986	0	1	1	0	0	0	0	0	
1987	0	0	6	0	0	0	1	0	
1988	0	0	5	0	2	0	2	0	
1989	0	2	0	0	1	0	4	1	
1990	0	1	0	2	0	0	1	0	
1991	0	0	1	0	1	0	0	0	
1992	0	1	3	0	0	0	1	0	
1993	1	0	3	0	1	0	0	0	
1994	0	9	2	0	6	0	2	0	
1995	4	0	8	1	16	0	9	0	
1996	1	1	5	0	4	1	6	0	
1997	0	9	0	3	5	3	0	0	
1998	2	3	13	1	11	7	8	7	
1999	1	5	6	1	1	2	1	3	
2000	0	2	0	0	1	3	0	0	
2001	0	0	1	1	2	1	0	0	
2002	0	12	3	0	0	0	9	0	
2003	0	11	4	9	4	18	0	7	
2004	2	1	2	7	6	10	1	6	
2005	2	0	15	0	11	0	0	0	
2006	0	0	0	0	5	0	0	2	
2007	0	0	7	0	8	1	8	2	
2008	0	1	0	1	0	2	1	1	
2009	0	0	4	1	3	1	2	0	
2010	0	7	0	0	0	0	0	0	
2011	0	2	0	2	1	9	1	5	
2012	2	8	13	1	9	9	8	6	
2013	0	5	0	2	7	10	2	3	
2014	0	12	0	6	6	1	10	2	
2015		8		9		10		5	

**Table 1 (b): Number of hot days (HD) and cold days (CD) over Bihar region**

Year	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	No of days (HD)	No of days (CD)	
	Chapra		Dehri		Supaul		Muzaffarpur		
1969	0	0	16		9		8		
1970	0	0	22				8		
1971	0	0	3	1			0		
1972	1	0			1		22		
1973	0	2					0	1	
1974	1	1	23				10		
1975	2	4	5						
1976	0		1						
1977	0		12						
1978	0		10		1				
1979	0		24		7				
1980	0		15						
1981	0		21		1	1		1	
1982	0		14	1	7				
1983	4	11	10			2	7	6	
1984	1		2			1	2	2	
1985	0				3				
1986	0							2	
1987	0	1	23				1	2	
1988	0		16						
1989	0		1				3		
1990	0		6				1	5	
1991	0		0				1		
1992	0		4				3	3	
1993	0		0				1	1	
1994	0		10				22		
1995	0						7	1	
1996	0						11		
1997	0							3	
1998	0								
1999	0		1					6	
2000	0		17					4	
2001	0		7					2	
2002	0		16				2		
2003	0		24	6			2	18	
2004	0		21	1			4	9	
2005	0						17	1	
2006	0						3	1	
2007	0						4	2	
2008	0								
2009	0						10	1	
2010	0								
2011	1	12					11		
2012	0	10			3	1	22		
2013	1	10	17	1	2	5	21	2	
2014	1	6	22	5	4	4	23	6	
2015		6		1		5		3	

**Table 2 (a): Number of heat wave (HW), severe heat wave (SHW) and cold wave (CW) and severe cold wave (SCW) over Bihar region**

Year	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	
	Patna		Patna		Gaya		Gaya		
1969	11	11	3	0	15	1	16	1	
1970	07	3	14	0	11	1	12	2	
1971	0	0	14	1	3	0	11	0	
1972	21	13	17	1	16	5	16	2	
1973	2	0	8	0	11	0	6	0	
1974	15	4	11	3	14	0	11	5	
1975	23	5	7	2	15	0	14	1	
1976	8	0	3	0	5	0	3	0	
1977	3	0	6	0	7	0	6	0	
1978	2	1	3	0	2	0	3	0	
1979	14	4	5	1	7	2	3	1	
1980	16	7	5	0	22	0	3	1	
1981	3	2	5	0	3	0	3	0	
1982	8	2	12	2	1	8	1	0	
1983	8	5	14	0	9	0	6	0	
1984	10	4	13	5	14	0	6	1	
1985	6	1	1	0	15	1	0	0	
1986	8	2	1	0	9	0	2	0	
1987	18	1	1	0	12	8	3	0	
1988	7	0	4	3	3	2	2	0	
1989	12	1	13	0	4	0	20	1	
1990	1	0	1	0	4	0	6	1	
1991	9	1	2	0	6	1	10	1	
1992	22	3	10	0	9	4	11	0	
1993	16	0	6	0	6	0	7	0	
1994	8	1	8	4	3	1	4	0	
1995	16	11	4	1	11	4	9	3	
1996	13	4	2	0	8	0	12	1	
1997	9	4	1	0	7	0	11	1	
1998	8	8	1	0	12	0	3	0	
1999	10	4	2	0	12	0	11	0	
2000	3	1	8	0	2	0	2	3	
2001	3	1	9	1	5	0	3	1	
2002	3	0	10	4	7	0	1	0	
2003	7	0	14	5	10	0	0	5	
2004	8	6	7	0	8	0	2	0	
2005	14	10	4	0	15	8	4	0	
2006	13	1	2	0	6	0	4	0	
2007	7	0	4	0	3	0	12	0	
2008	6	0	4	0	10	0	9	0	
2009	14	5	2	0	20	2	3	1	
2010	1	3	1	0	2	0	7	1	
2011	6	5	9	2	9	3	16	4	
2012	17	14	3	1	15	10	10	0	
2013	6	0	11	1	6	0	9	4	
2014	22	1	6	2	11	0	18	0	

**Table 2 (b): Number of heat wave (HW), severe heat wave (SHW) and cold wave (CW) and severe cold wave (SCW) over Bihar region**

Year	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	
	Bhagalpur		Bhagalpur		Purnea		Purnea		
1969	7	1	4	1	1	5	2	2	
1970	9	3	0	0	2	2	1	3	
1971	0	0	3	0	0	0	3	3	
1972	14	2	5	0	2	11	3	5	
1973	10	0	2	0	6	4	2	1	
1974	8	0	4	1	1	0	3	2	
1975	6	0	2	0	1	0	5	1	
1976	2	0	1	0	1	1	4	0	
1977	4	0	2	0	1	0	7	0	
1978	1	0	5	0	0	1	6	0	
1979	14	1	0	0	6	14	6	0	
1980	12	5	0	0	3	1	2	0	
1981	7	4	0	0	0	0	3	0	
1982	15	11	0	0	1	8	4	1	
1983	12	8	9	1	4	0	3	4	
1984	13	1	0	0	0	0	2	0	
1985	8	1	0	0	1	3	0	0	
1986	9	0	3	0	1	1	0	0	
1987	17	0	1	0	1	0	0	0	
1988	14	4	1	0	7	0	8	0	
1989	8	1	7	1	5	10	8	0	
1990	6	0	6	7	1	0	5	0	
1991	4	0	0	0	1	2	4	0	
1992	18	1	0	0	6	8	0	0	
1993	3	0	0	0	0	0	9	1	
1994	9	3	0	0	4	5	11	2	
1995	14	4	2	1	3	11	1		
1996	15	1	0	0	7	3	0		
1997	14	1	1	0	0	0	3		
1998	12	6	3	0	0	8	4		
1999	16	0	5	0	3	2	3		
2000	3	1	2	0	0	3	0		
2001	3	0	3	0	2	3	0		
2002	1	0	1	0	0	1	0		
2003	2	1	2	12	0	1	4		
2004	4	3	0	0	0	1	0		
2005	13	2	0	0	0	2	0		
2006	5	0	0	0	1	1	0		
2007	2	1	0	0	1	7	0		
2008	4	0	0	0	1	0	2		
2009	10	0	0	1	5	3	1	0	
2010	1	0	0	0	0	0	0	0	
2011	3	2	20	12	2	4	4	0	
2012	13	1	8	2	4	8	3	0	
2013	2	0	14	7	2	0	5	0	
2014	10	1	0	16	3	12	1	0	



**Table 2 (c): Number of heat wave (HW), severe heat wave (SHW) and cold wave (CW) and severe cold wave (SCW) over Bihar region**

Year	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	
	Chapra		Chapra		Dehri		Dehri		
1969	11	1	3	1	15	6	0	0	
1970	10	4	3	0	18	8	0	0	
1971	0	0	1	0	0	0	0	0	
1972	15	5	7	0	11	4	0	0	
1973	10	1	1	0	10	3	0	0	
1974	11	0	6	1	19	7	5	3	
1975	9	0	2	0	4	2	6	5	
1976	0	0	1	0	2	2	8	4	
1977	3	0	2	0	10	4	8	3	
1978	0	0	0	0	12	1	6	0	
1979	7	0	1	0	17	9	0	0	
1980	9	3	2	0	11	6	1	0	
1981	0	0	0	0	17	11	0	0	
1982	3	2	1	0	10	8	0	0	
1983	5	0	3	0	8	4	0	1	
1984	3	0	1	4	9	0	7	6	
1985	8	1	4	0	6	1	9	5	
1986	11	0	1	0	7	3	7	3	
1987	12	5	3	1	22	9	3	4	
1988	2	0	0	0	19	3	8	3	
1989				0	5	1	4	6	
1990				0	8	0	3	4	
1991				0	7	3	7	6	
1992			1	0	14	8	8	3	
1993			9	10	12	5	0	2	
1994			0	0	1	0	0	0	
1995	16	5	2	1	0	0	0		
1996	12	0	6	0	0	0	0		
1997					0	0	0		
1998					0	0	6		
1999					7	1	0		
2000					12	7	0		
2001					9	0	0		
2002					12	8	0		
2003					16	9	5	3	
2004					13	12	3		
2005									
2006									
2007									
2008									
2009									
2010									
2011	6	6	18	15					
2012	19	9	14	9			4	3	
2013	2	0	6	14	12	7	6	3	
2014	15	0	17	2	16	8	5	2	

**Table 2 (d): Number of heat wave (HW), severe heat wave (SHW) and cold wave (CW) and severe cold wave (SCW) over Bihar region**

Year	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	No of days (HW)	No of days (SHW)	No of days (CW)	No of days (SCW)	
	Muzaffarpur		Muzaffarpur		Supaul		Supaul		
1969	7	4	14	2	8	4	2	1	
1970	5	6	8	1	0	0	4	0	
1971	0	0	6	1	0	0	7	0	
1972	16	12	4	0	4	3	5	2	
1973	0	0	1	0	7	2	1	1	
1974	10	3	1	0	1	0	6	0	
1975	0	0	0	0	0	0	8	5	
1976	0	0	0	0	0	0	9	2	
1977	0	0	0	0	0	0	8	0	
1978	0	0	0	0	0	1	1	2	
1979	3	1	0	0	10	4	2	0	
1980	6	1	0	0	1	0	1	0	
1981	0	3	0	0	1	0	0	1	
1982	6	3	4	1	9	3	2	0	
1983	2	4	11	2	0	0	3	0	
1984	2	0	12	2	0	0	4	0	
1985	0	0	0	0	5	1	0	0	
1986	0	0	2	0					
1987	6	3	0	0					
1988	6	0	2	0					
1989	8	4	14	3					
1990	2	0	7	0					
1991	2	0	1	0					
1992	9	0	3	1					
1993	0	0	3	1					
1994	3	4	3	0					
1995	9	18	9	0					
1996	0	0	0	0					
1997	4	4	0	0					
1998	0	0	0	0					
1999	8	10	2	0					
2000	1	0	2	0					
2001	0	1	5	2					
2002	2	0	0	0					
2003	1	0	16	9					
2004	0	3	11	2					
2005	12	8	0	0					
2006	3	1	1	0					
2007	3	2	0	0					
2008	0	0	0	1					
2009	10	4	1	0					
2010	0	3	4	0			7	3	
2011	6	9	9	1	2	4	4	1	
2012	16	11	7	4	2	3	2	6	
2013	13	9	6	3	2	1	8	5	
2014	17	9	1	0	4	10	8	2	

**Table 3 (a): Decadal frequency of day hot and day cold over Bihar region**

	decade	Patna	Gaya	Bhagalpur	Purnea	Chapra	Dehri	Supaul	Muzaffarpur
Hot days	D1	9	32	18	26	7	114	16	9
	D2	1	25	11	14	0	60	3	32
	D3	2	42	50	34	0	86	0	26
	D4	4	39	50	32	3	39	9	111
	decade	Patna	Gaya	Bhagalpur	Purnea	Chapra	Dehri	Supaul	Muzaffarpur
Cold days	D1	13	3	0	3	15	1	4	9
	D2	14	2	0	1	1	0	0	13
	D3	44	23	45	23	0	7	0	43
	D4	35	13	33	21	38	6	10	13

**Table 3 (b): Decadal frequency of heat wave and cold wave over Bihar region**

	decade	Patna (HW)	Gaya (SHW)	Patna (CW)	Patna (SCW)	Gaya (HW)	Gaya (SHW)	Gaya (CW)	Gaya (SCW)
days	D1	95	30	73	10	85	10	48	4
	D2	107	10	47	7	71	17	65	3
	D3	80	39	58	11	82	4	54	14
	D4	106	39	46	6	97	23	92	10
	decade	Bhagalpur (HW)	Bhagalpur (SHW)	Bhagalpur (CW)	Bhagalpur (SCW)	Purnea (HW)	Purnea (SHW)	Purnea (CW)	Purnea (SCW)
days	D1	86	30	19	1	17	25	42	6
	D2	96	10	47	7	71	17	65	3
	D3	84	39	58	11	82	4	54	14
	D4	63	39	46	6	97	23	92	10
	decade	Chapra (HW)	Chapra (SHW)	Chapra (CW)	Chapra (SCW)	Dehri (HW)	Dehri (SHW)	Dehri (CW)	Dehri (SCW)
days	D1	39	5	13	4	100	47	36	19
	D2	33	6	18	11	101	33	49	36
	D3	28	5	8	1	69	37	14	3
	D4	42	39	46	6	97	23	92	10
	decade	Muzaffarpur (HW)	Muzaffarpur (SHW)	Muzaffarpur (CW)	Muzaffarpur (SCW)	Supaul (HW)	Supaul (SHW)	Supaul (CW)	Supaul (SCW)
days	D1	19	12	27	5	21	8	38	10
	D2	36	11	35	5				
	D3	25	36	45	13				
	D4	80	56	29	9	10	18	22	14

**Table 3 (c): Decadal frequency of heat wave and cold wave (normal + severe) over Bihar region**

	decade	Patna (H)	Patna (C)	Gaya (H)	Gaya (C)	Bhagal pur (H)	Bhaga lpur (C)	Purne a (H)	Purnea (C)
days	D1	125	83	95	52	116	20	42	48
	D2	117	54	88	68	106	54	88	68
	D3	119	69	86	68	123	69	86	68
	D4	145	52	120	102	102	52	120	102
	decade	Chapra (H)	Chapra (C)	Dehri (H)	Dehri (C)	Muzaff arpur (H)	Muzaff farpur (C)	Supaul (H)	Supaul (C)
days	D1	44	17	147	55	31	32	29	48
	D2	39	29	134	85	47	40		
	D3	33	9	106	17	61	58		
	D4	81	52	120	102	136	38	30	46

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